LArSoft/Tools Update

Eric/Herb

February 2, 2012

Outline

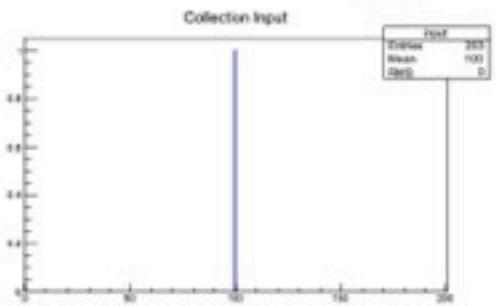
- LArSoft developments since last meeting
- uBooNE codebase
- toward a uBooNE data challenge

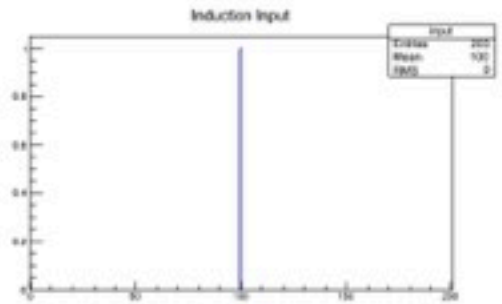
uBooNE electronics: backstory

Updated Idealized MicroBooNE Performance

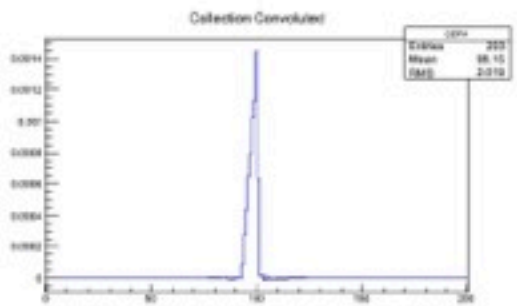
t_s=500 ns

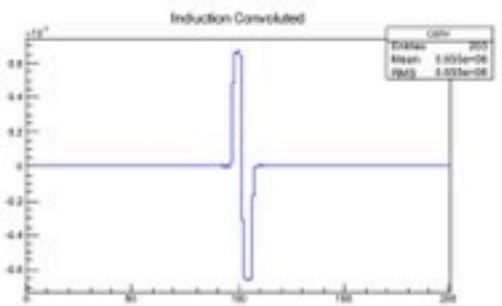
Input



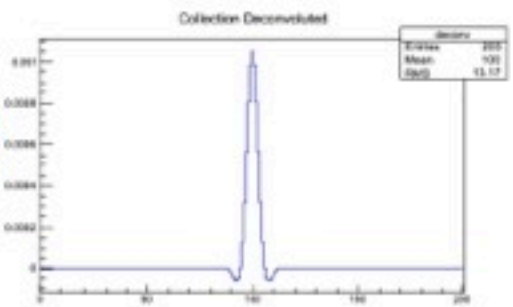


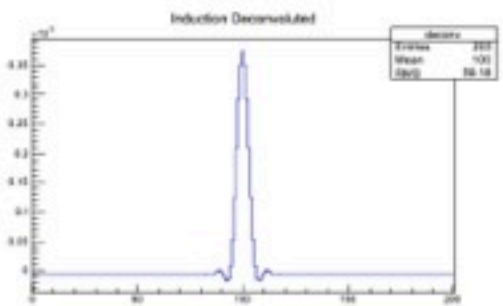
Convoluted





Deconvoluted

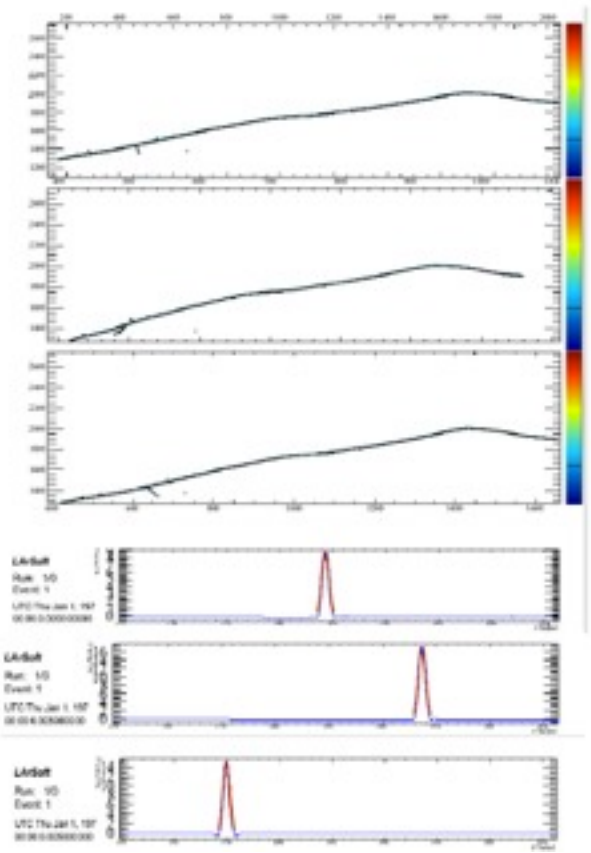




uBooNE electronics: backstory 2

A Reconstructed MicroBooNE Event

$t_s = 500$ ns



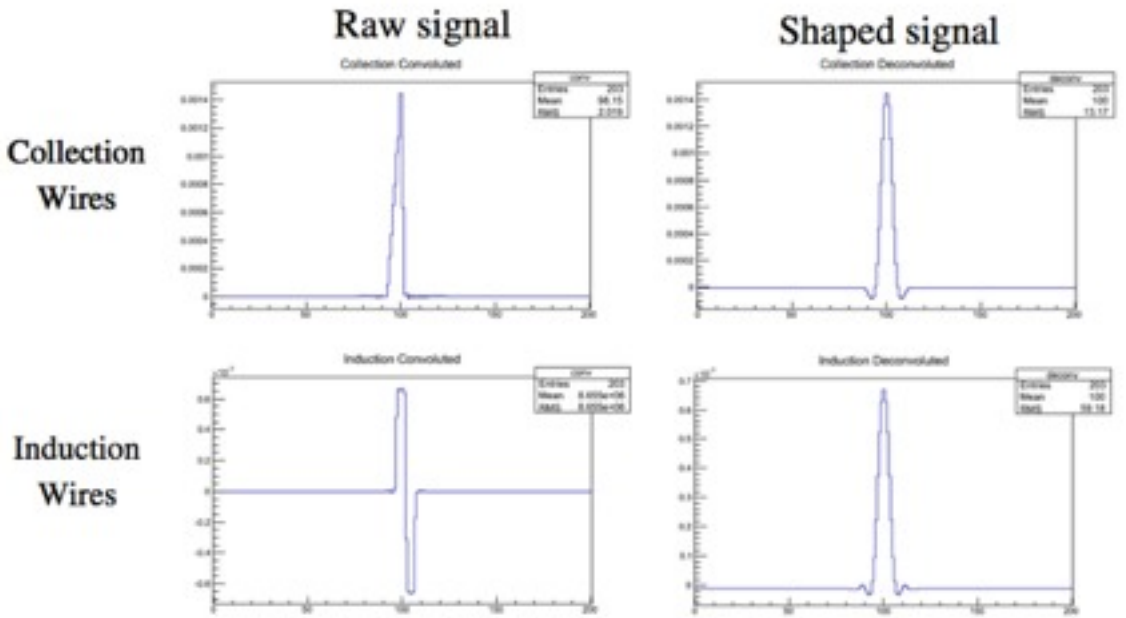
Can now digitize at the right sampling rate and extract hits after all signal processing: this is a big deal.

New electronics developments

- Short version: deconvolution kernel is now calculated on the fly by SignalShapingServiceMicroBooNE without the need to read data from files (also includes hard-coded parameterizations of field response and electronics response).

MicroBooNE CalWire Normalization

- CalWire normalization is now fixed such that deconvoluted signals have the same peak height as raw signals.



LArSoft developments

- Birk's Law fix (Ornella)

MC DATA:

- Used to prove the reliability of the calorimetric reconstruction

- Simulation of events in LArSoft:
  a) in LArVoxelReadout::DriftIonizationElectrons the energy deposited (from GEANT4) in a Voxel is converted in # of electrons taking accounting for:
     1. charge loss due to electro-negative impurities (lifetimecorrection)
     2. charge to energy conversion with correction for the quenching effect (recomb)

nElectrons = lifetimecorrection * energy * recomb * nElectrons_const

lifetime τ=750 μs and Elec. Field=500 V/cm

recomb is calculated from the parameterization in ICARUS, NIM 523 (2004), 2

$$A_{3t} = 0.800 \pm 0.003,$$

$$k_{3t} = 0.0486 \pm 0.0006 \text{ kV/cm} \frac{\text{g/cm}^2}{\text{MeV}}$$

$$\left(k_Q = \frac{k}{\mathcal{E}}\right). \qquad (9)$$

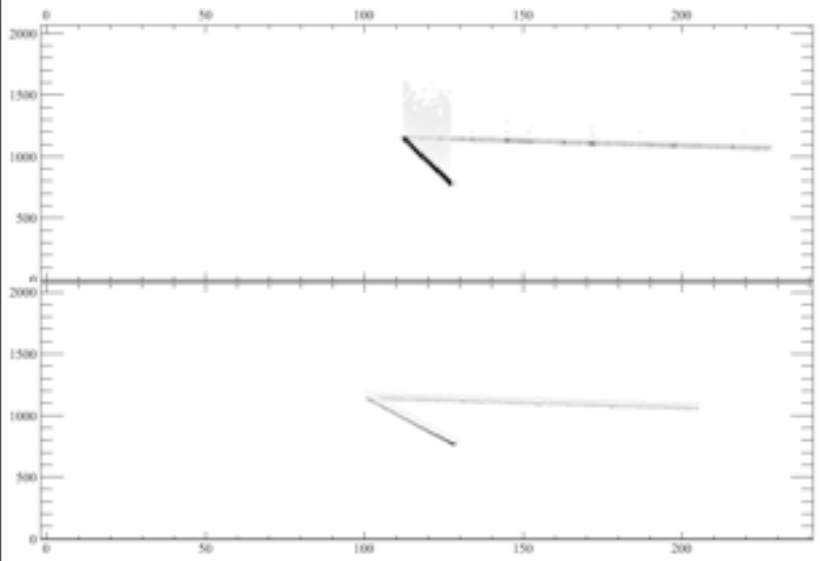
Corresponding to $k_Q = 0.097 \pm 0.001$ (g/cm^2)/MeV at 0.5 kV/cm, in good agreement with the value in Ref. [3].

$$Q = A \frac{Q_0}{1 + k/\mathcal{E}\, \mathrm{d}E/\mathrm{d}x}$$

recomb = fRecombA/(1. + (energy/dx)*fRecombk);

[MeV/cm]*[g/cm^2/MeV] !

0) **CCQE (GENIE)** events in ArgoNeuT (generated by Kinga)



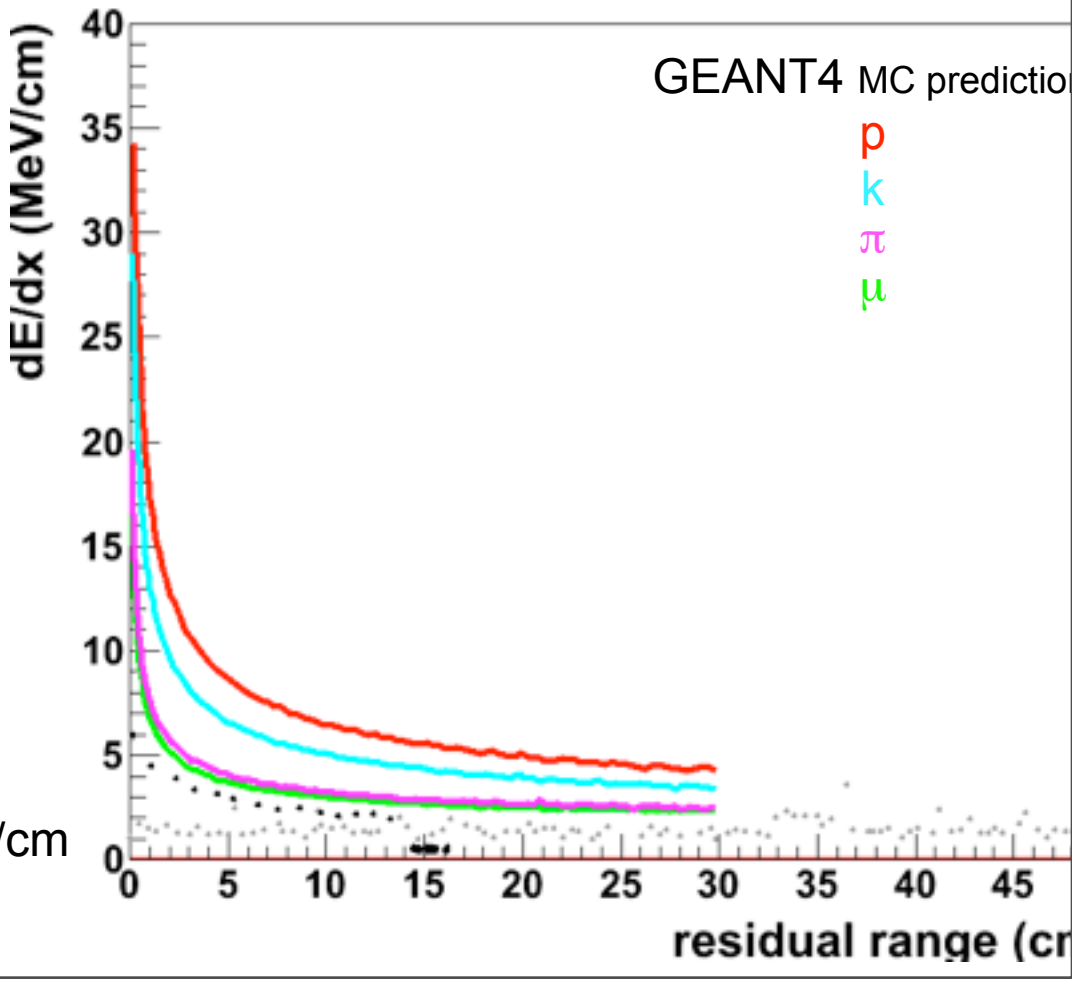
Raw data

After reconstruction:

black points: rec. MC p
grey points: rec. MC μ

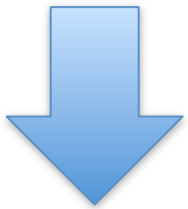
Very far from GEANT prediction!!!

1.5 MeV/cm



Change to the recombination factor in LArSoft, to include the LAr density (Jan. 13 2012)

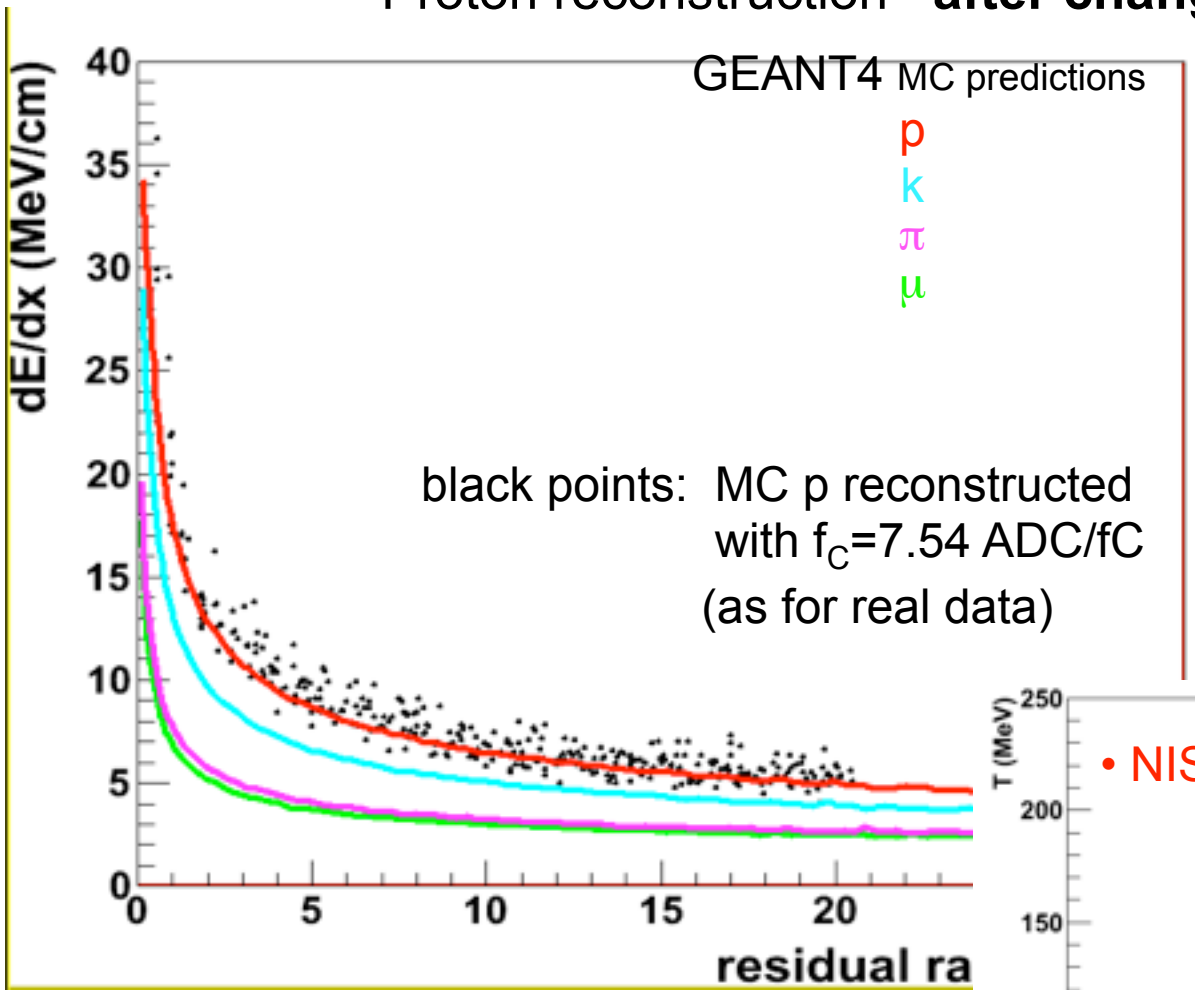
fRecombk = lgp->Recombk()/**density**;

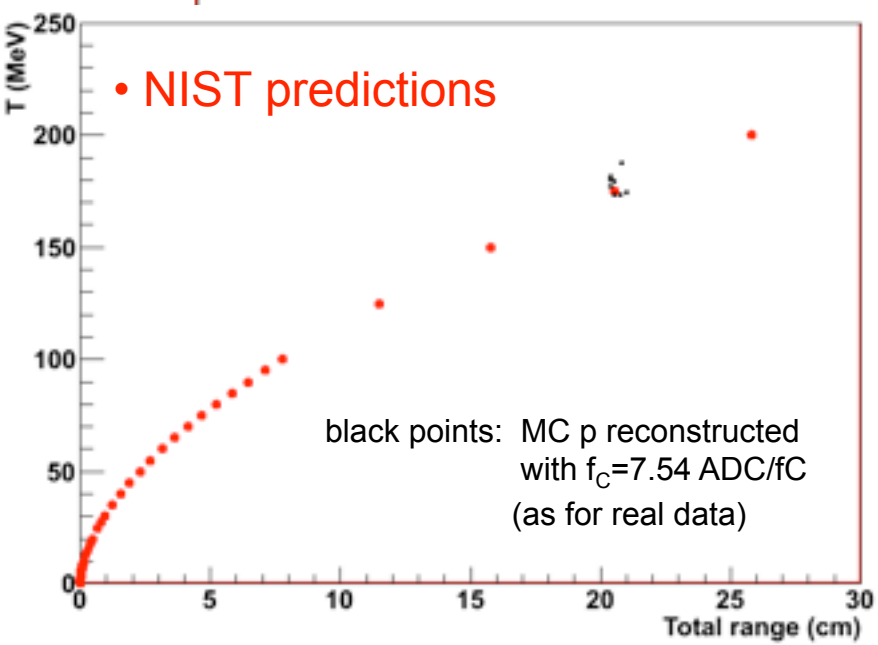


1) **GeV Muons** - tracks parallel to the wire plane **– after change**
raw **MC** data Coll. Plane ~ 26 ADC; <dQ/dx>=63 ADC/cm,
from calorim. Rec. <dE/dx>=2.2 MeV/cm in agreement with real data

[*to be compared with: raw Real data Coll. Plane ~ 26 ADC; <dQ/dx>=63 ADC/cm; <dE/dx>=2.2 MeV/cm]*

Proton reconstruction –**after change**:





Good agreement with GEANt-NIST prediction!!!!

• The **missed density** in the recombination formula had relevant impact on MC simulated events!

•After the change: MC and real RAW data agree!!!

•Calorimetric reconstruction works properly both for real and MC data

To be done:

- Test on MC neutrino events (ex. CCQE events - Kinga);

- Calculate threshold for proton reconstruction (OP-Kinga);

- Test calorimetric reconstruction for MicroBooNE.

Spacepoints in eventdisplay

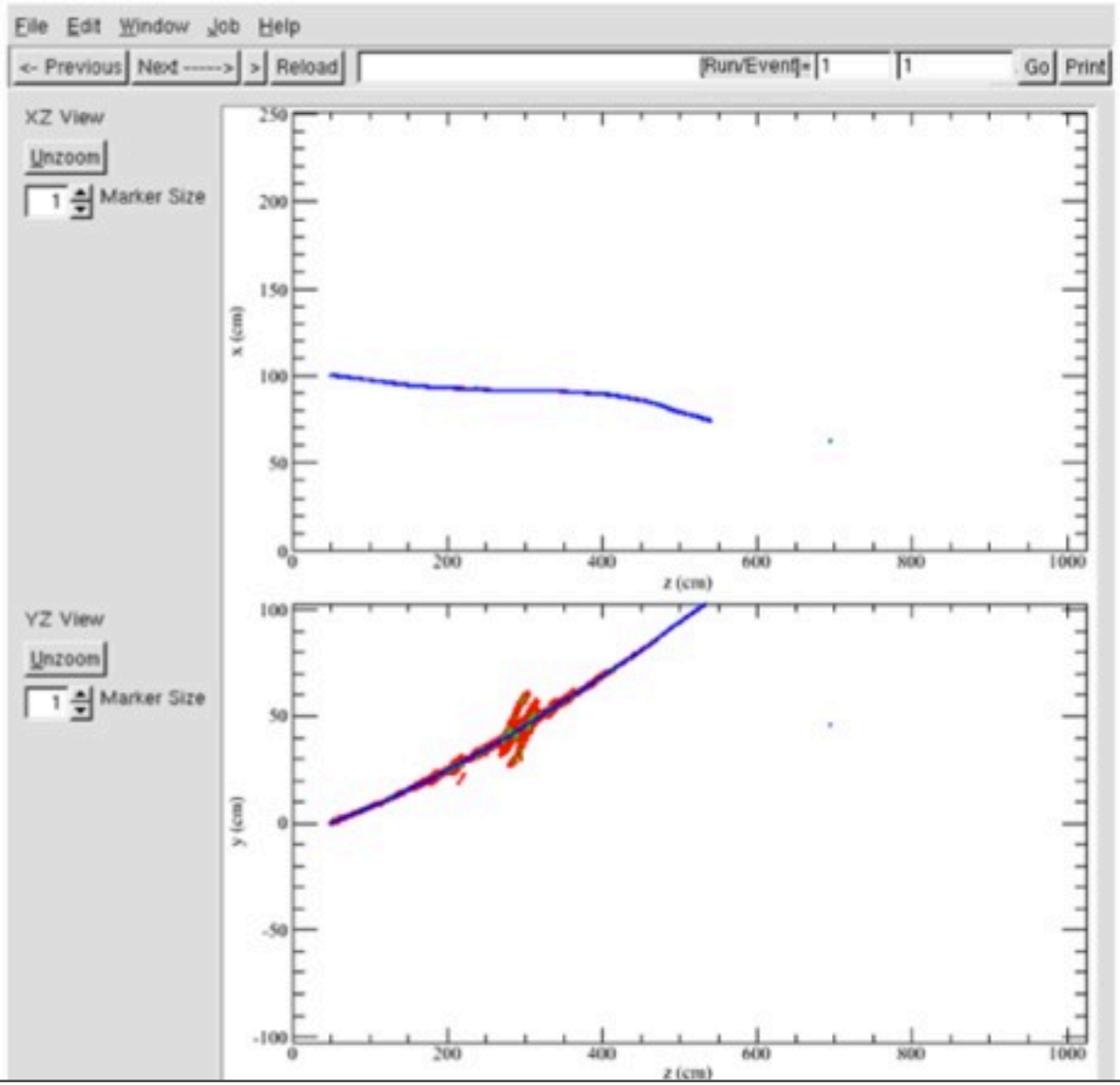
Ortho3D View Features

- Display space points stored in prongs.
  - Use SpacePointFinder or SpacePointCheater modules to make prongs.
- Two orthographic views currently: XZ and YZ.
- Zoomable
- Adjustable size markers (useful feature of Open GL 3D display).
- Color options (also available in full 3D display).
  - Default – different colors for different prong objects.
  - By type (ColorProngsByLabel = 1) – different colors for different types of prongs (e.g. regular vs. mc truth prongs).
  - By chisq (ColorSpacePointsByChisq = 1) – generate color according to space point chisquare (not in svn).

LarSoft developments

XZ view
(looks similar to
time vs. wire view)

YZ view



Spacepoints: event display 2

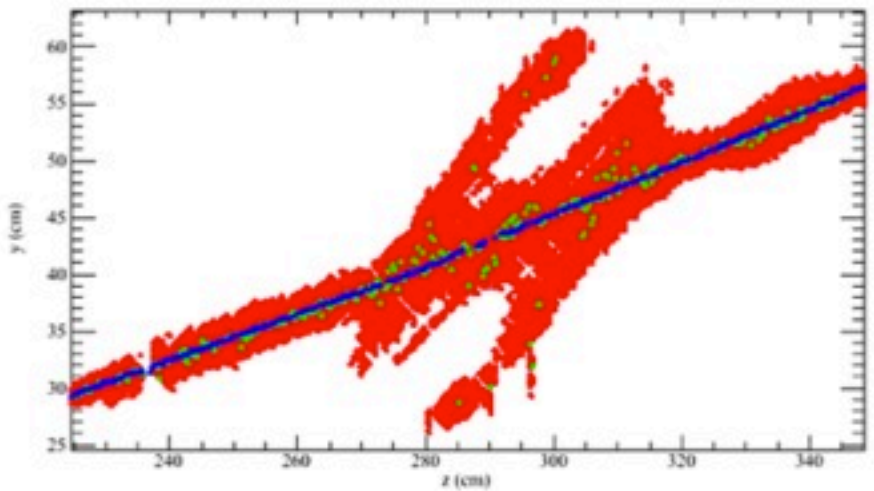
Ortho 3D View Color Options

Color by type

Blue = Truth

Green = Filtered

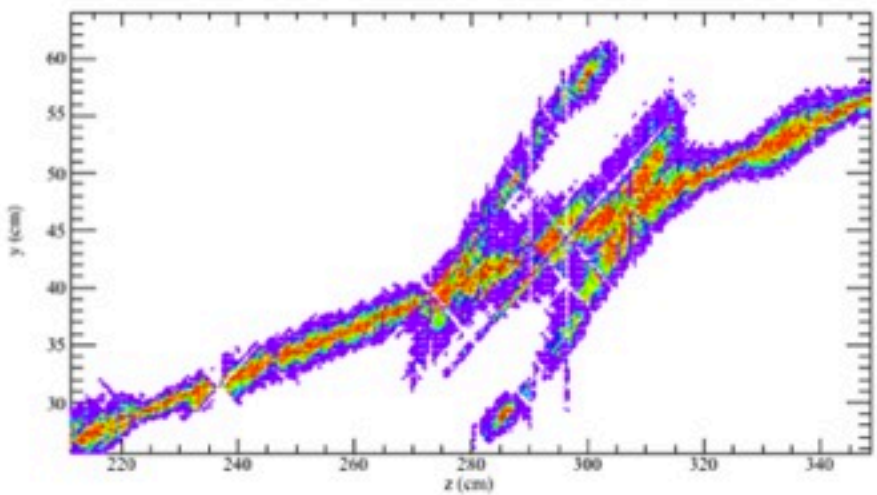
Red = All



Color by chisquare

Red = Better

Blue = Worse

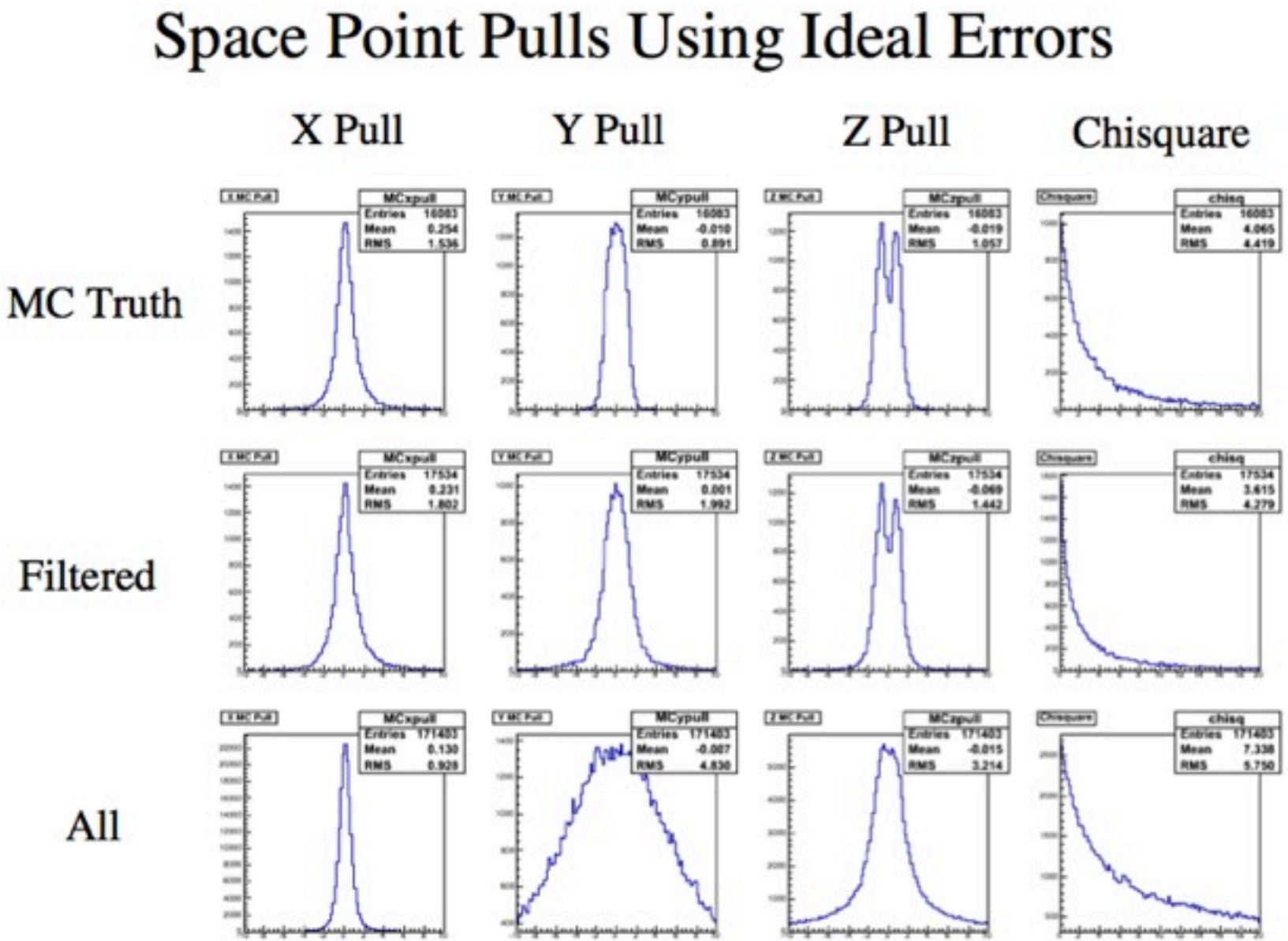


Spacepoints: errors

Adding Errors to Space Points

- Space Points currently have as attributes a list of hits (art::PtrVector<recob::Hit>) and spatial coordinates (x,y,z).
- Proposal: add the following attributes.
  - Error matrix (3x3 symmetric matrix – 6 values).
  - Chisquare.

Spacepoints: pulls



LArSoft developments

- Unit Tests (Bill S, Brian R)

- Especially with lots of new users coming Brian and I have pushed this issue a little higher up the list. Any software shop has a bunch of jobs which run executables on the nightly build to test it against results of a frozen build. This is roughly what we'd like.
- For now, Bill/Brian have installed a simple `lar` MC/recon job that runs on a cron schedule every evening after the build. It reports an email on error. We would like to flesh this out to run a Root macro on diagnostic histograms to look for differences. A good grad student service project.

LArSoft developments

- bi-directional one-to-many and vice-versa Associations (Brian R, CD ARTists).

- This means, for example, hit objects know their parent raw signal (digits) objects and their cluster objects to which they belong. Vertices know their tracks, tracks know their vertices. Some code-rewriting, but should be non-disruptive. This isn't quite yet implemented, though it's in the codebase. We (wearing my LArSoft hat now) will freeze LArSoft before implementation.

LArSoft Developments

- Track3DKalman (Eric)

- Merely a status update, unlike previous Progress reports.

- I know my problem which has prevented multiple scattering extraction of track momentum. I understand why -- and have affirmed that -- till now I have merely extracted momentum from the track length.

LArSoft developments

- How much of this do you really want/need/ care to know.
- But, perhaps some of the sausage making is worth seeing.
- Everything I've said about hits in "noisy" regions causing the Kalman fitter trouble should be regarded now with deep suspicion. Problem is/was more fundamental than that.

Kalman Filter

$$\vec{x_k} = \tilde{\vec{x_k}} + K_k \vec{r_k}$$

This is the Kalman update at each k.

$$C_k = (I - K_k H_k)\tilde{C}_k$$

where

$$\vec{r_k} = \vec{m_k} - H_k \tilde{\vec{x_k}}$$

The ˜ denotes a predicted quantity. k labels a point on the track. x is the state space and m is the measurement. They are connected by H. The Kalman gain is

$$K_k = \tilde{C}_k H_k^T (H_k \tilde{C}_k H_k^T + V_k)^{-1}$$

Kalman filter

$$\vec{x} = \begin{pmatrix} \frac{q}{|p|} \\ \frac{du}{dz} \\ \frac{dv}{dz} \\ u \\ v \end{pmatrix}$$

This came with Genfit out of the box. I only recently realized it's fatally deficient for our purposes.

$$H = \begin{pmatrix} 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

Sum over all points, k=1,N. Ndof=2N.

$$\chi^2 = \vec{r_k}^T (V_k - H C_k H^T)^{-1} \vec{r_K}$$

Kalman filter (last)

- With this 2x5 H, which I inherited and thought was fine in the Genfit codebase, I will never update p, du/dw, dv/dw, and hence never change direction or deduce the correct momentum, except as ionization energy loss requires.

- I have the new 5x5 H. Am checking Jacobians, etc, making progress ...

$$H = \begin{pmatrix} 13.6MeV/\beta \cdot \sqrt{\frac{x}{14cm}} & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

Toward a uBooNE codebase

- We have a repository designated for this with merely place-holder code in it. This is not news.

- Herb and I and others believe there will be a need for this in the next year, as code is developed. If nothing else, useful Root macros that may have generic applicability can go here.
- It is also true that LAr40 and LAr1 are suddenly seeing an influx of workers.

Toward a uBooNE codebase

- Putting on my/Herb's Tools Coordinator Hat now: The one-size fits all LArSoft approach may break as simulations of these multi-cryo, multi-TPC, wrapped wire detectors mature.
- It's already true we have code with names like CalWireMicroBoone, SimWireMicroBooNE, SignalShapingMicroBooNE, because the electronics is detector specific. That code right there could/should go into `https://cdcvs.fnal.gov/redmine/projects/ubooneoffline/repository`

Toward a uBooNE codebase

- The cleanest approach involves building our code against a frozen LArSoft codebase.
- ArgoNeuT began going down this path and, to my understanding, pulled back and decided against it. LArSoft is still quite young and almost all fixes are truly needed and we must live on dev as long as we can.
- That said, Herb/I are watching the timing here to split off and live against a frozen LArSoft build.

Toward a Data Challenge

- This has been discussed in the past.
- It would be nice to have some data samples in a public directory, like /uboone/data/users/samples.Fall.2012/ which collaborators can begin to look at with some of the aforementioned Root macros in the uboone repository.
- We can now probably recon up through hits, clusters, spacepoints. Perhaps by Fall also TrackKalman, Showers, HoughLines in the planes.

Toward a Data Challenge 2

- We think Recon steps are now speedy enough (10s of seconds per event at least for muons) to do this. IF Grid usage is understood and well exercised.
- We'd imagine single muons of course, single electrons, pi0s, charged pis...
- Genie neutrino events.

- This may be well-timed with the new liquid argon transition at LBNE. They want to do a big, new hand scan study on Genie events. It will likely be done in the uBooNE detector geometry.

Toward a data challenge 3

- It seems to mandatory that we overlay cosmics on whatever we run, or at least on most of them. We will have 3-4 kHz * 1.6 msec ~ 5 cosmics per drift "frame."

- We have one Yale undergrad who's doing this as she can find time.
- I am repeating myself, but it's imperative to get someone to shake out CRY and the overlay process and soon, in time for a would-be data challenge.